Coulomb breakup of ^{8}B within a Dynamical Eikonal Approximation

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Outline

- Introduction on ^{8}B
- Dynamical eikonal description of breakup
- Coulomb breakup of ^{8}B
  - comparison with experiments
  - role of nuclear interaction, E1-E2 interferences, higher-order effects,...
- Conclusions

What makes ^{8}B so interesting?

- Very low $S_p = 137$ keV $\Rightarrow$ one-p halo candidate:

$$^8\mathrm{B} \equiv {}^7\mathrm{Be} + \mathrm{p}$$

  Breakup used to study halo nuclei

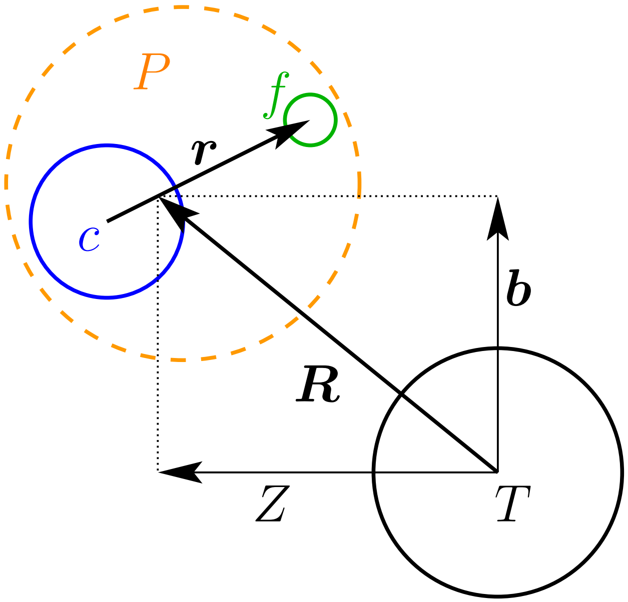
- Coulomb breakup of astrophysical interest:
  Inverse reaction of $^7\mathrm{Be}(\mathrm{p}, \gamma)^8\mathrm{B}$,
  important for solar neutrino studies (cf. SNO)
  Idea: extract $\sigma_{\mathrm{capture}}$ from σ_{bu}, but
  - Influence of nuclear interaction in breakup ?
  - Only E1 in capture, while also E2 in breakup
  - Role of higher-orders in breakup ?

We propose a study of the Coulomb breakup of ^{8}B addressing these issues

Framework

Projectile (P) modelled as a two-body system:
core (c)+loosely bound nucleon (f) described by

$$H_0 = T_r + V_{cf}(\boldsymbol{r})$$



V_{cf} adjusted to reproduce bound state

Target T seen as structureless particle

P-T interaction simulated by optical potentials
$\Rightarrow$ breakup reduces to three-body scattering problem:

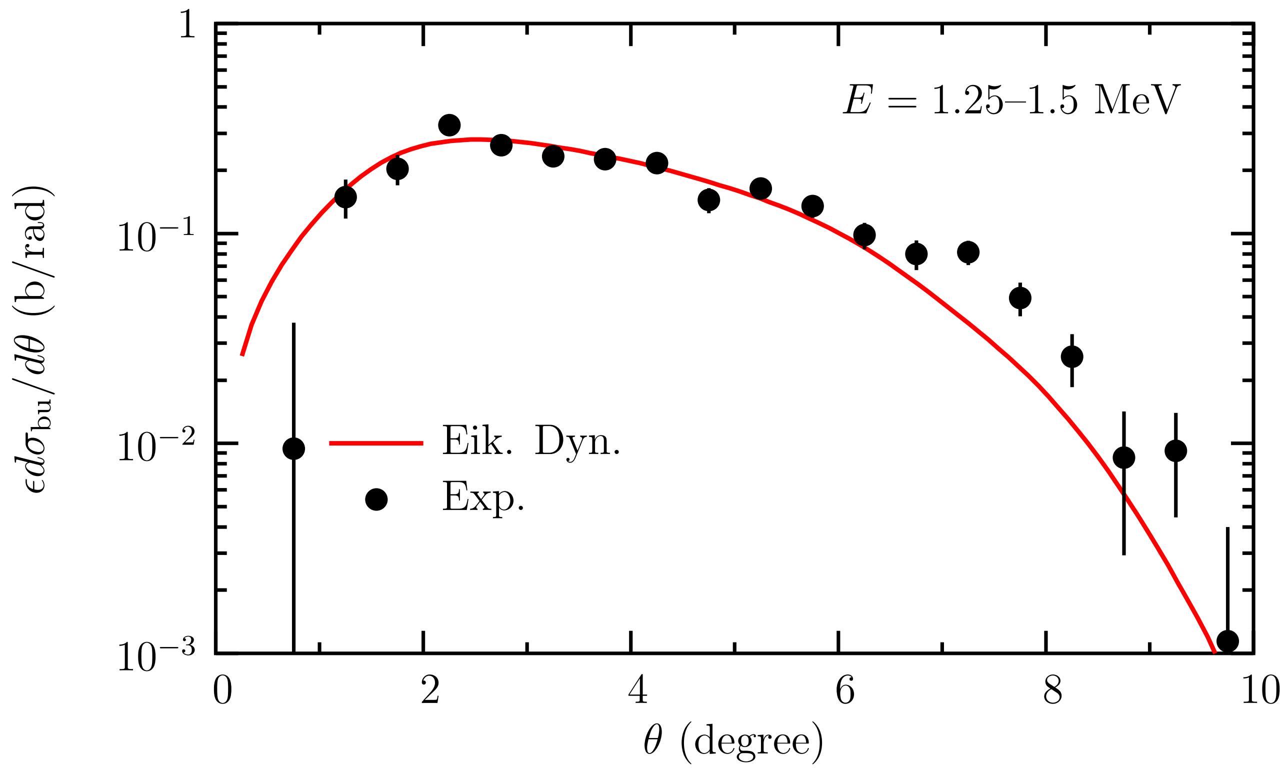
$$[T_R + H_0 + V_{cT} + V_{fT}]\,\Psi(\boldsymbol{R},\boldsymbol{r}) = E_T\Psi(\boldsymbol{R},\boldsymbol{r})$$

solved using Dynamical Eikonal Approximation

Baye, PC, Goldstein PRL 95, 082502 (05); PRC 73, 024602 (06)

Angular distribution

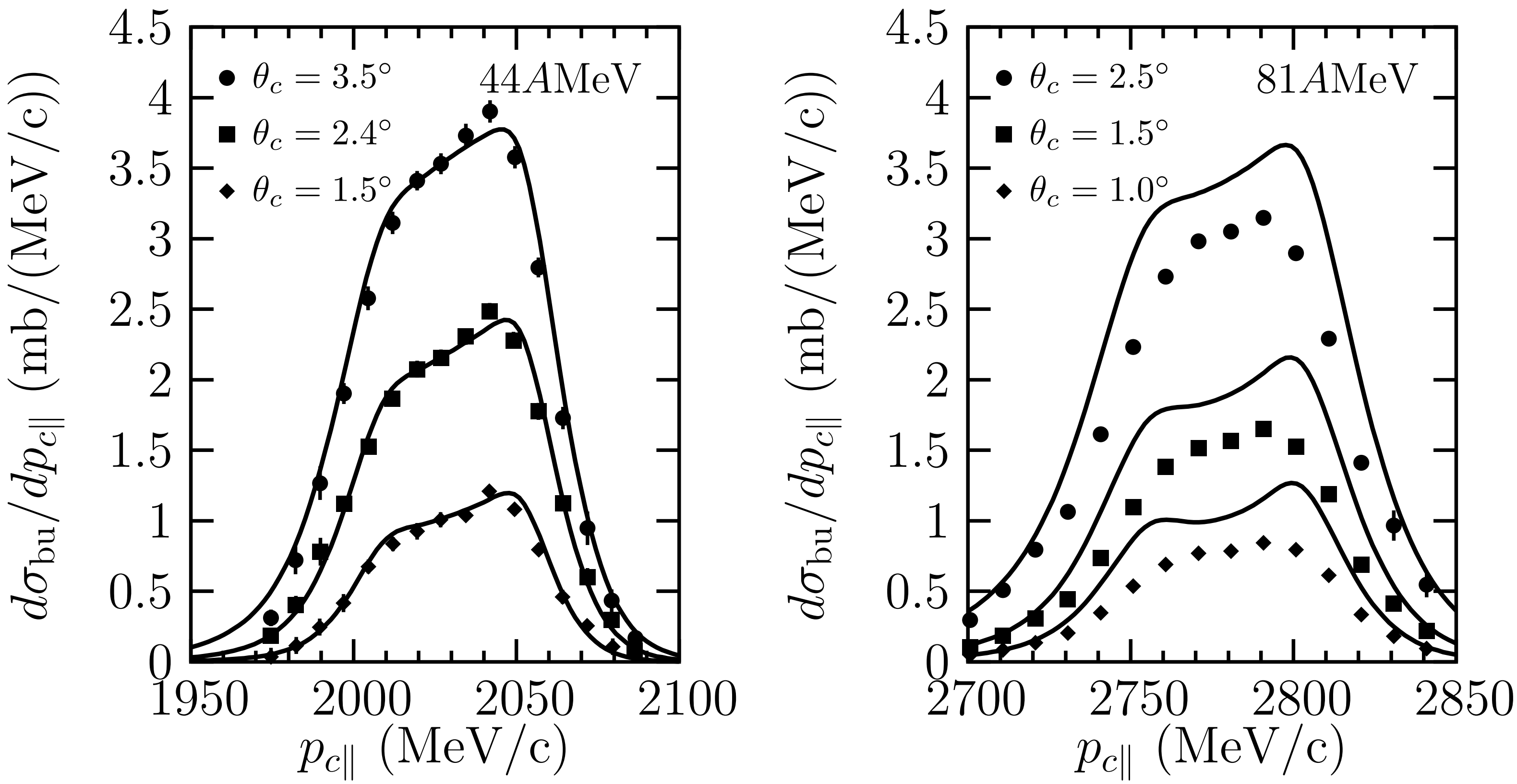
^{8}B + Pb @ 52AMeV (RIKEN) [Kikushi PLB 391, 261 (97)]



- Data well reproduced by Dynamical Eikonal with 2-body model of ^{8}B (no fitting parameter)
- Slight underestimation at large angle (nuclear)

Parallel-momentum distributions

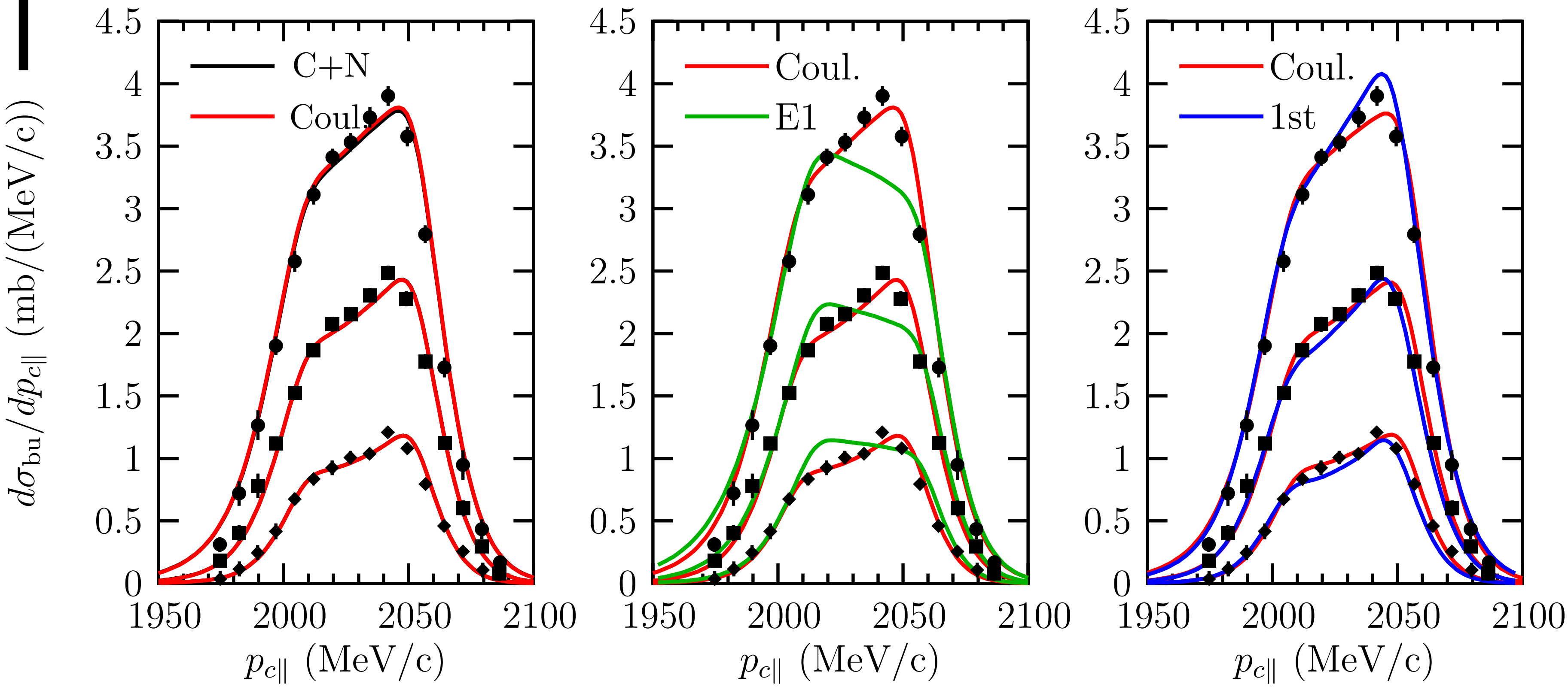
^{8}B + Pb @ 44 & 81AMeV (MSU) [Davids PRL 81, 2209 (01)]



- Good agreement of Dynamical Eikonal with exp. (no fitting parameter)
- Asymmetry in data due to E1-E2 interference

Analysis

^{8}B + Pb @ 44 AMeV (MSU) [Davids PRL 81, 2209 (01)]



Nuclear interaction negligible at forward angles

Significant E1-E2 interference (asymmetry)

First-order: too asymmetric
⇒ higher-order

Conclusion

- Study of Coulomb breakup of ^{8}B
- New reaction model: Dynamical Eikonal Approx.
- Good agreement with experiment
  for various observables and energies,
  without fitting parameters,
  only one reaction model, and one ^{8}B description
- Nuclear interaction negligible at forward angle
- Large E1-E2 interference in breakup
- Significant higher-order effects

$\Rightarrow \sigma_{\text{capture}}$ cannot be extracted directly from σ_{bu}
but might be infered from the ^{8}B description

Dynamical eikonal approximation (1)

Three-body scattering problem

$$[T_R + H_0 + V_{cT} + V_{fT}]\,\Psi(\boldsymbol{r},\boldsymbol{R}) = E_T\Psi(\boldsymbol{r},\boldsymbol{R})$$

with condition $\Psi(\boldsymbol{r},\boldsymbol{R}) \underset{Z\to-\infty}{\longrightarrow} e^{iKZ}\Phi_0(\boldsymbol{r})$

To remove the rapid variation in $\boldsymbol{R}$ we factorise $\Psi(\boldsymbol{r},\boldsymbol{R}) = e^{iKZ}\widehat{\Psi}(\boldsymbol{r},\boldsymbol{R})$:

$$\begin{aligned} H\Psi &= e^{iKZ}[T_R + vP_Z + \frac{1}{2}\mu_{PT}v^2 \\ &\quad + (H_0 + V_{cT} + V_{fT})]\widehat{\Psi} \end{aligned}$$

Neglecting T_R vs P_Z and using $E_T = \frac{1}{2}\mu_{PT}v^2 + E_0$

$$i\hbar v\frac{\partial}{\partial Z}\widehat{\Psi}(\boldsymbol{r},\boldsymbol{b},Z) = [H_0 - E_0 + V_{cT} + V_{fT}]\widehat{\Psi}(\boldsymbol{r},\boldsymbol{b},Z)$$

Dynamical eikonal approximation (2)

$$i\hbar v \frac{\partial}{\partial Z}\widehat{\Psi}(\boldsymbol{r},\boldsymbol{b},Z) = [H_0 - E_0 + V_{cT} + V_{fT}]\widehat{\Psi}(\boldsymbol{r},\boldsymbol{b},Z)$$

is equivalent to a TDSE with straight line trajectories but here $\boldsymbol{b}$ and Z are quantal

The usual eikonal uses adiabatic approx. $H_0 - E_0 \sim 0$
$\Rightarrow$ neglects dynamical effects

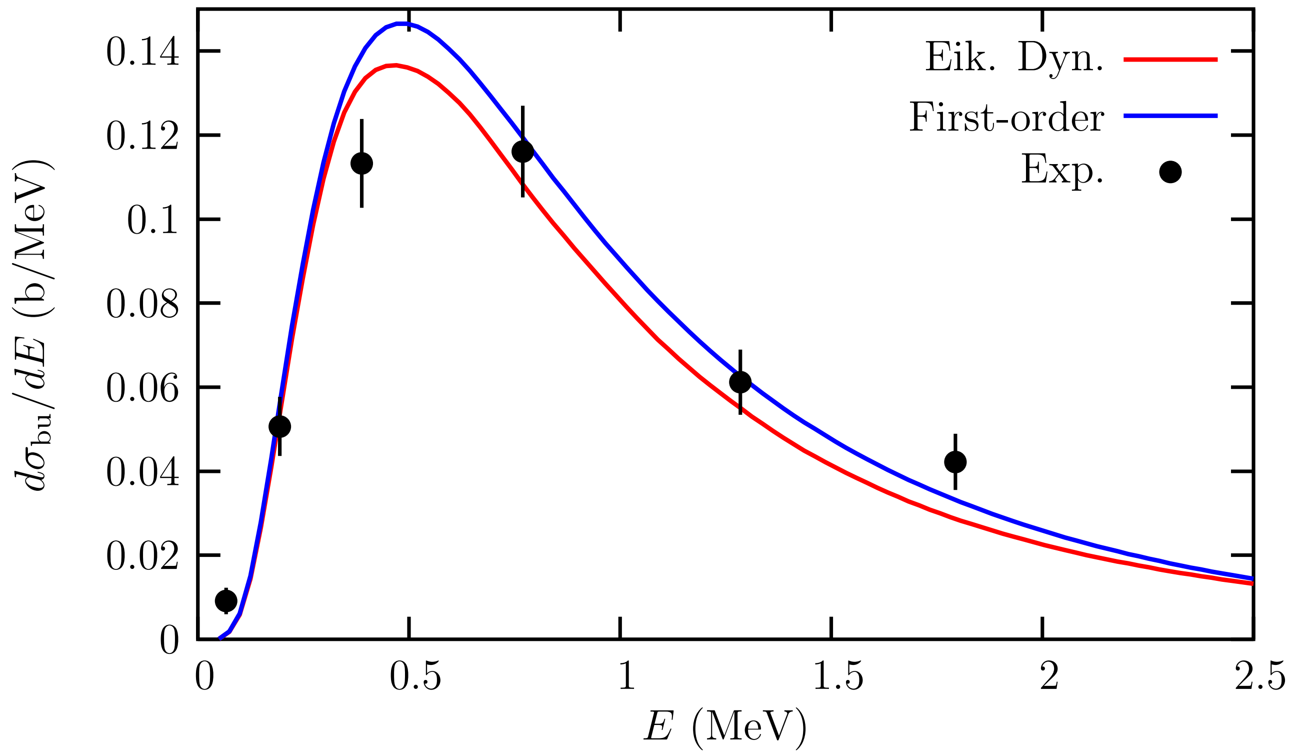
$$\widehat{\Psi}^{\text{eik}}(\boldsymbol{r},\boldsymbol{b},Z) = e^{-\frac{i}{\hbar v}\int_{-\infty}^{Z} dZ' \left[V_{cT}(\boldsymbol{r},\boldsymbol{b},Z') + V_{fT}(\boldsymbol{r},\boldsymbol{b},Z')\right]}\Phi_0(\boldsymbol{r})$$

$\Rightarrow$ dynamical eikonal generalises eikonal and TDSE

- improves eikonal by including dynamical effects
- improves TDSE by including interferences
- we know how to solve accurately TDSE

Energy distribution

^{8}B + Pb @ 83AMeV (MSU) [Davids PRL 83, 2750 (01)]



- Good agreement with experiment (no parameter)
  $\Rightarrow$ confirms the validity of the model
- First order also valid